

# COMPARATIVE STUDY BETWEEN TRADITIONAL TENOLYSES AND WITH INTRAOPERATIVE AWAKENING PERFORMED ON THE FLEXOR OSTEOFIBROUS TUNNEL REGION OF THE HANDS (ZONE 2)

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## ABSTRACT

**Objective:** Flexor tendon tenolysis on zone 2 is a difficult and really challenging for hand surgery. With the objective of comparing the results obtained between tenolyses with intraoperative awakening, performed with locoregional anesthesia (group 1), from those obtained with traditional tenolysis performed under general anesthesia or total blockage of the brachial plexus (group 2), the authors conducted a prospective and controlled study. **Methods:** 22 patients with 39 fingers with flexor tendon injuries on zone 2 evolving to adhesions were assessed. All patients were operated after three months and before one year of the primary tendinous suture. All patients showed limited active motion not improved by rehabilitation. Groups 1 and 2 showed to be homogenous concerning patients' age and gender, preoperative compromising, and absence of

associated injuries or pathologies. All patients were assessed according to active motion (TAMs) both preoperatively and at 6 months postoperatively. **Results:** The statistical analysis of data obtained for groups 1 and 2 shows that the tenolysis performed with both techniques produce good results. By comparing the results for total active motion after six months of the tenolysis, group 1 patients (treated by the intraoperative awakening technique) were found to present better outcomes. **Conclusions:** Flexor tenolysis on zone 2 provide good results in terms of joint range of motion. The intraoperative awakening technique with locoregional anesthesia provides improved outcomes when compared to the traditional technique.

**Keywords** – *Finger injuries; Tendon injuries; Tendons/surgery; Rehabilitation*

## INTRODUCTION

Injuries to the flexor tendons in zone 2 are severe, for they affect the important function of handgrip, and their treatment is complex. Its reconstruction is difficult because sutures require the strength to support traction of the flexor muscles, and at the same time the need to maintain an ability to glide to provide the flexion necessary for finger movements. Besides, in zone 2, nearly all flexor tendons are surrounded by a synovial sheath and are nourished by blood through those connections. The superficial and deep tendons of the fingers have a complex relationship of gliding and flexion and act in several joints. These anatomical features make their surgical repair more difficult<sup>(1)</sup>.

The healing of tendons has been controversial for many years. Initially it was believed that tendons healed through fibroblasts from the digital sheath or neighboring tissues, and that nutrition was provided through adhesion with these structures<sup>(2,3)</sup>. However, it was demonstrated that tendons can heal satisfactorily exclusively through synovial nutrition and that the collagen necessary for healing can be produced by tenocytes<sup>(4-6)</sup>.

Intrinsic tendon healing begins with the proliferation of epitendon cells that grow along the tendon at the location of injury, forming a sort of "callous", similar to that which forms on the skin or on bone tissue<sup>(4,7)</sup>. Later, fibroblasts and tenocytes invade the

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“callous” and produce the collagen that will organize and align itself, producing a normal tendon. It appears that the support provided through synovial nutrition is sufficient to sustain this entire process. Adhesions formed during extrinsic healing seem to not be essential to the healing or nutrition of the tendon<sup>(7)</sup>.

The basic function of the flexor tendon is the gliding that moves the finger. Tendon adhesions can occur due to several mechanisms of injury to tendons (cut-contusion, laceration, avulsion, crushing), surgical manipulation, as a result of fractures or infectious processes<sup>(8,9)</sup>. Some adhesions can be successfully treated with the appropriate rehabilitation techniques. When there is no improvement and a great difference exists between the active and passive range of movement, there may be an indication for a tenolysis procedure<sup>(9,10)</sup>. Tenolysis consists of the release of all adhesions between the flexor tendon and its surrounding structures while preserving the local anatomy, particularly the system of pulleys, the joint capsule, volar plate, vessels, and nerves<sup>(9-12)</sup>.

Most authors have recommended that tenolysis should not be performed within three months of or one year after primary tenorrhaphy surgery. Prior to three months, the process of tendon healing may not provide sufficient mechanical strength to support the surgical aggression of tenolysis. On the other hand, surgery performed after a year is usually technically more difficult by virtue of the magnitude of adhesions and joint stiffness<sup>(13-17)</sup>.

Once surgical release is performed, the arc of movement of the impaired finger should be restored and rehabilitation program should quickly be implemented that mainly includes the passive and active movement of the operated finger. Rehabilitation should be started soon after surgery and continue until the range of movement remains stable<sup>(12,17)</sup>.

There is controversy regarding the type of anesthesia and the surgical technique to be used. While some authors use general anesthesia or a brachial plexus block, others prefer more distal blocks, with the goal of maintaining flexor muscle function (extrinsic or extrinsic and intrinsic) and allow for testing of the release of the adhered flexors by active movement after intraoperative awakening. Schneider and Hunter recommend the use of local anesthetics in combination with intravenous sedation so that the patient can participate actively in the flexor tendon release proce-

dure<sup>(9,18)</sup>. Other authors recommend the use of general anesthesia, especially when wounds are large or when use of the pneumatic cuff exceeds one hour<sup>(10)</sup>. There is also the argument that some patients will not accept or do not react well to the intraoperative awakening. When tenolysis is performed under general anesthesia or a brachial plexus block, the surgeon must be sure that all adhesions were released and that the patient will achieve the entire possible range of movement. Some authors recommend making an additional incision at the wrist to permit access and traction of the released flexor tendon, with the aim of testing the achieved degree of range of motion and releasing residual adhesions<sup>(10)</sup>.

Most of the time, the incision, whether medio-lateral or Brunner-type, is the same as that used in primary tenorrhaphy surgery. The adhered tendon is usually released by gentle dissection techniques that preserve neighboring structures. When intraoperative awakening is performed with locoregional anesthesia, the release is performed more or less in stages. After dissection and release of the tendon in the area that is considered critical, the patient is awakened by use of flumazenil, and is then asked to force active flexion. If the release is not sufficient to reestablish the entire possible range of movement (active movement equal to passive movement), the tenolysis procedure is extended to the more proximal or distal area.

There are no comparative studies between the conventional technique performed under general anesthesia or total brachial plexus block and that with intraoperative awakening under distal locoregional anesthesia.

In order to compare these two techniques, we conducted a controlled prospective study in patients undergoing tenolysis for the treatment of tendon adhesions in zone 2 of the flexor osteofibrous tunnel.

## METHODS

Between 2000 and 2008, 12 patients with 20 fingers with tendon adhesions in the flexor system in the osteofibrous tunnel region (zone 2) were operated with intraoperative awakening and locoregional anesthesia, which were denominated group 1. The control group (group 2) consisted of ten patients with 19 fingers with tendon adhesions in zone 2 who underwent conventional tenolysis under general anesthesia or total brachial plexus block.

All patients had tendon adhesions in zone 2 with more than three months and less than one year since tenorrhaphy. Patients with other hand injuries, such as fractures, peripheral nerve damage, loss of skin cover, etc., were excluded. Patients with diabetes, vascular disorders, arthritis, osteoarthritis, and other conditions that could compromise the functional outcome of the tenolysis procedure and rehabilitation were not included in this study. All patients were operated by the same surgical team and all were evaluated preoperatively and six months postoperatively following the same protocol.

The patients' age, gender, and impaired fingers are shown in Table 1.

The surgical technique used for both groups was based on the same incision (mediolateral or Brunner-type) used for tenorrhaphy, dissection of the flexor tendons while preserving the pulley system, releasing all adhesions and mobilization of the finger.

In group 1, patients underwent block anesthesia with 0.5% bupivacaine in the wrist and the palm, in

the topography of the median, ulnar, and radial nerves and their branches, in combination with sedation with propofol or midazolam. In group 2, patients underwent general anesthesia or (axillary or interscalene) proximal blocks in combination with sedation. In group 1, after the surgical release of adhesions, patients were awakened by an anesthesiologist using 0.2 to 0.6 mg of flumazenil, and were then asked to perform active flexion and extension. In cases where the desired movement was not achieved, tenolysis was extended until active movement reached the passive range of movement of the finger.

In group 2, after surgical release of adhesions, the proximal segments of the tendons were pulled until the passive range of movement of the finger was attained (Figure 1).

After tenolysis, careful hemostasis was performed, as were wound closure, dressing, and bandaging of the hand and fingers. In group 1, while still under local anesthesia, patients were encouraged to actively move the finger and observe the result achieved in terms of gains in the range of motion (Figure 2).

Patients were referred to the hand therapy clinic and followed the same protocol, which included active and passive movements of the operated finger, anti-edema measures and tendon adhesions with bandaging and healing massage.

Measurements of the range of movement of the proximal and distal interphalangeal joints were obtained before surgery and six months postoperatively. Measurements of the total active motion (TAM) modified by Strickland were recorded and the values of the two groups were compared statistically by the Wilcoxon test and the Mann-Whitney test. Nonparametric tests were adopted because the samples did not show normal distribution.



**Figure 1** – Case 2 in group 2 (tenolysis under general anesthesia). Note the finger flexion achieved thanks to the traction of the proximal tendon in the wrist region

**Table 1** – Distribution of the gender and age of the patients studied

Finger	Group 1			Group 2		
		Age	Gender		Age	Gender
1	case 1 finger 1	22	male	case 1 finger 1	33	male
2	case 1 finger 2			case 1 finger 2		
3	case 2 finger 1	37	male	case 1 finger 3		
4	case 2 finger 2			case 2 finger 1	24	female
5	case 3 finger 1	32	female	case 3 finger 1	55	male
6	case 4 finger 1	42	male	case 3 finger 2		
7	case 4 finger 2			case 3 finger 3		
8	case 4 finger 3			case 4 finger 1	25	male
9	case 5 finger 1	46	female	case 4 finger 2		
10	case 5 finger 2			case 4 finger 3		
11	case 6 finger 1	53	male	case 5 finger 1	47	male
12	case 6 finger 2			case 5 finger 2		
13	case 7 finger 1	21	male	case 5 finger 3		
14	case 7 finger 2			case 6 finger 1	33	male
15	case 8 finger 1	41	male	case 7 finger 1	29	male
16	case 9 finger 1	27	female	case 8 finger 1	22	female
17	case 10 finger 1	31	male	case 9 finger 1	33	male
18	case 10 finger 2			case 10 finger 1	29	male
19	case 11 finger 1	39	male	case 10 finger 2		
20	case 12 finger 1	29	male			
	Mean	35.00		Mean	33.00	
	Standard deviation	9.72		Standard deviation	10.42	

## RESULTS

Group 1 TAM values measured in the preoperative period and six months postoperatively are shown in Table 2. Data evaluation and statistical analysis show that there is a significant difference between the TAM measurements pre- and postoperatively.

The TAM values measured in the preoperative period and six months postoperatively in group 2 are shown in Table 3. The evaluation of the data shows that there is a difference, as shown by statistical studies, between the TAM measurements pre- and postoperatively.



**Figure 2** – Case 8 in group 1 (tenolysis under locoregional anesthesia with digital nerve block of the median nerve). Note that after the release of adhesions, the patient can perform the total active flexion and extension of the impaired finger

A comparison of TAM measurements in the preoperative period in groups 1 and 2 shows that these are homogeneous, with no statistical difference between the data (Mann-Whitney test –  $p > 0.05$ ).

A comparison of TAM measurements in the postoperative period in groups 1 and 2 shows that the results are different, with statistically significant differences between the data obtained. This shows that the group treated with intraoperative awakening and locoregional anesthesia (group 1) provides results superior to six months postoperatively (Mann-Whitney test –  $p < 0.05$ ).

## DISCUSSION

The flexor tenolysis procedure can be considered a challenge in achieving the goal of improving digital function. There is consensus that the pre-requisites for success include an experienced surgical team, a well-informed and motivated patient, and a careful

**Table 2** – Distribution of TAM measurements in group 1 in the preoperative period (pre-TAM) and six months postoperatively (post-TAM)

Finger	Group 1		
		Pre-TAM value	Post-TAM value
1	case 1 finger 1	70.00	170
2	case 1 finger 2	65.00	165
3	case 2 finger 1	110.00	180
4	case 2 finger 2	90.00	185
5	case 3 finger 1	60.00	170
6	case 4 finger 1	65.00	165
7	case 4 finger 2	50.00	170
8	case 4 finger 3	110.00	180
9	case 5 finger 1	100.00	175
10	case 5 finger 2	70.00	180
11	case 6 finger 1	40.00	150
12	case 6 finger 2	50.00	140
13	case 7 finger 1	65.00	170
14	case 7 finger 2	55.00	180
15	case 8 finger 1	90.00	170
16	case 9 finger 1	70.00	180
17	case 10 finger 1	65.00	185
18	case 10 finger 2	60.00	180
19	case 11 finger 1	50.00	180
20	case 12 finger 1	45.00	185
	Mean	69.00	173.00
	Standard deviation	20.69	11.63
	Wilcoxon test $p < 0.05^*$		

program of hand therapy<sup>(9,14,15)</sup>. In some situations, it is not possible to accurately determine the location and extent of tendon adhesions<sup>(9)</sup>. For some surgeons, the use of local anesthesia is greatly advantageous for providing analysis of the treatment of tendon adhesions and capsular release during surgery<sup>(9,18)</sup>. However, there are no studies proving the benefits of the use of locoregional anesthesia and tests with intraoperative awakening. The indications for tenolysis cover clinical situations in which the passive mobility is much greater than the active<sup>(13)</sup>. There is also consensus that the system of pulleys should be preserved or reconstructed in tenolysis procedures, and that active movement during surgery can facilitate this procedure<sup>(8,13,15)</sup>. If appropriate treatment is performed, the tenolysis procedure provides a high degree of patient satisfaction<sup>(12,14,15)</sup>. On the other



**Table 3** – Distribution of TAM measurements in group 2 in the preoperative period (pre-TAM) and six months postoperatively (post-TAM)

Finger	Group 2		
		Pre-TAM value	Post-TAM value
1	case 1 finger 1	80.00	150
2	case 1 finger 2	75.00	140
3	case 1 finger 3	90.00	130
4	case 2 finger 1	100.00	180
5	case 3 finger 1	70.00	160
6	case 3 finger 2	70.00	150
7	case 3 finger 3	90.00	130
8	case 4 finger 1	120.00	150
9	case 4 finger 2	110.00	140
10	case 4 finger 3	100.00	120
11	case 5 finger 1	60.00	150
12	case 5 finger 2	60.00	145
13	case 5 finger 3	70.00	140
14	case 6 finger 1	50.00	130
15	case 7 finger 1	60.00	180
16	case 8 finger 1	45.00	135
17	case 9 finger 1	50.00	140
18	case 10 finger 1	50.00	180
19	case 10 finger 2	40.00	180
	Mean	73.16	148.95
	Standard deviation	23.17	18.90
Wilcoxon test $p < 0.05^*$			

hand, the tenolysis procedure may be even more difficult than primary suture because it involves a previously operated area and, in some patients, the results can be disastrous, with worsening of function, especially in cases of tendon rupture<sup>(17)</sup>.

In order to evaluate the use of locoregional anesthesia procedures, we decided to compare the results of tenolysis performed by this method with those obtained with conventional tenolysis with general anesthesia or total blockade of the brachial plexus. Our initial hypothesis is that patients who undergo flexor tenolysis of zone 2 under locoregional anesthesia and with intraoperative awakening have more satisfactory results due to the better interpretation of the release of adhesions and preservation of the pulley system provided by the active movement of the tendon. Likewise, the greater involvement of patients in the postoperative period, generated by the motivation to observe the recovery of the range of motion intraoperatively, should assist in achieving better results.

In order to assess homogeneous groups of patients, we included only patients with tendon adhesions in zone 2, with surgery for primary suture of flexor tendons between three and 12 months of the indication of tenolysis without associated injuries (fractures, ligament injuries, loss of skin cover, etc.) or any other diseases (diabetes, vascular disorders, osteoarthritis, arthritis, etc.).

Patients with inclusion criteria were then divided into group 1 (tenolysis with locoregional anesthesia and intraoperative awakening) or 2 (control – tenolysis with general anesthesia or total blockade of the brachial plexus).

The average age of both groups was similar, 35 years for group 1 and 33 years for group 2, with no great significant distinction in relation to gender (75% of patients in group 1 and 80% in group 2 were males) (Table 1).

The surgical technique in both groups was similar with respect to the surgical approach, preservation of the pulley system, preservation of the flexor tendons, release of adhesions, hemostasis, wound closure, rehabilitation, and mobilization of the finger. The difference between the groups was based only on the tenolysis technique of intraoperative assessment: in group 1, patients were tested for active flexion of the finger after intraoperative awakening and in group 2, the tendons were pulled by the surgeon in the region proximal to the tenolysis.

All patients followed the same treatment protocol in rehabilitation, including active and passive exercises, anti-edema measures, adhesion prevention measures, and functional training. Patients were evaluated according to the range of joint motion measured by the Strickland method, which is based on the sum of the range of flexion of the proximal and distal interphalangeal joints minus the extension deficiency of these same joints (TAM – Total active motion modified by Strickland)<sup>(13)</sup>, preoperatively and at six months postoperatively.

The analysis of data obtained in group 1 shows that the tenolysis with locoregional anesthesia and intraoperative awakening provides good results. We see great improvement in joint range of movement between the preoperative measurement and six months after tenolysis. This evaluation demonstrates that the technique adopted promotes improved movement

of the impaired finger (Table 2). Similarly, analysis of the data obtained in group 2 also shows that conventional flexor tenolysis under general anesthesia or brachial plexus block provides good results, promoting an improvement of movement (Table 3).

When comparing the data on the active mobility of the impaired fingers in the preoperative periods (preoperative TAM) of group 1 and 2, we observed no differences in relation to impairment. These data also confirm the homogeneity of the samples, which was one of the methodological goals of this study (Tables 2 and 3).

When comparing the results of total active motion six months after tenolysis, we observed that the group of patients treated with locoregional anesthesia and intraoperative awakening had better results. Although flexor tenolysis in zone 2 conventionally performed using general anesthesia or total blockade of the brachial plexus provided an improved range of movement of impaired fingers, this technique can be implemented even when using locoregional anesthesia and active movement with intraoperative awakening. Perhaps active movement of the finger during surgery, thanks to locoregional anesthesia and

intraoperative awakening, can help the surgical team to better determine whether all tendon adhesions were actually released. Likewise, active movement of the finger can help the surgical team to preserve important structures such as the pulley system and tendon structure. As to the patient, it seems that the memory of obtaining active movement during surgery is a motivating factor towards greater dedication to rehabilitation. Patients undergoing locoregional anesthesia and intraoperative awakening seem to have the goal of, at the least, maintain what was achieved during the surgical procedure.

## CONCLUSIONS

This prospective, comparative, and controlled study concluded that flexor tenolysis in zone 2 for the treatment of tendon adhesions after primary tendon suture provides good results in terms of gains in the range of motion. We also conclude that tenolysis under locoregional anesthesia with intraoperative awakening allowing active movement of the finger provides more satisfactory results than the conventional technique performed under general anesthesia or total blockade of the brachial plexus.

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